

SEWER SYSTEM EVALUATION STUDY GWYNNNS FALLS SEWERSHED STUDY AND PLAN

4.0 Sewer System Evaluation Study

4.1 Overview

The sewer system evaluation study (SSES) is defined as the inspection and condition assessment of the wastewater collection system. The inspection regime included:

- i. CCTV inspection of all sewers (with the exception noted in Items ii, iii, and iv) that were 8 inches in diameter and larger
- ii. Sonar and CCTV inspection of sanitary sewer interceptors operating at higher flow depths than those permitted by PACP
- iii. Soil corrosion and resistivity tests, and coupon sampling for the Westport Pump Station Main for which CCTV could not be completed due to its pressurized operation
- iv. Sonar inspection of the siphons on the Gwynns Falls Interceptors for which CCTV could not be completed due to pressurized operation
- v. Visual inspection of all manholes and other wastewater collection system appurtenances (e.g. junction chambers, siphon chambers, etc.)
- vi. Smoke testing
- vii. Dyed flooding tests and dyed water tests

The completed inspection program included 995,165.50 lf of CCTV inspections and 4,320 manhole inspections.

Based on a review of the inspection data, a rehabilitation and corrective action plan was developed to address critical defects.

4.2 Manhole Inspections

Manhole inspections were completed to identify manhole defects and determine the defects' severity. The inspections began in September 2007 and were substantially completed in November 2009. Manholes were inspected as required by the Consent Decree in accordance with general guidelines outlined in the Environmental Protection Agency (EPA) SSES Handbook, the American Society of Civil Engineers (ASCE) Manhole Inspection and Rehabilitation Manual 92, and the newly defined requirements of the National Association of Sewer Service Companies (NASSCO) Manhole Assessment and Certification Program (MACP). In order to standardize all manhole inspections throughout the collection system, the City implemented the use of the Manhole Inspection Application Software (MIAS) developed for the City by Rummel, Klepper & Kahl, LLP. For the safety of the crews, a remote manhole inspection camera was utilized to inspect and view defect images and observations in lieu of manned-entry to complete the majority of the inspections. Manhole condition assessment observations were recorded and documented in a manner consistent with MACP guidance. Manholes that could not be located or opened for inspection were documented. Inspection of these manholes will be attempted again during the Gwynns Falls re-inspection program (reference Section 7.5.2). These structures will be inspected and incorporated into the City's overall rehabilitation plan.

The following is a brief description of the process involved in the collection of manhole inspection data for the Gwynns Falls Sewershed. The following descriptions are not intended to cover all aspects of the work performed, rather to provide a general understanding of the data collection and review process.

SEWER SYSTEM EVALUATION STUDY GWYNNNS FALLS SEWERSHED STUDY AND PLAN

- A manhole inspection crew consisting of 2 inspectors used a 1" = 100' scale GIS map to identify manholes to be inspected. This map contained information such as street names, manhole location and ID, flow direction and connectivity of the system with all other upstream and downstream manholes.
- The crew selected a manhole from the database list of manholes, went to the location where the manhole was shown on the GIS map, and performed a visual search in an effort to locate the manhole or structure for inspection. If found, the manhole location was visually compared with the location indicated on the GIS map. Any discrepancies between the two locations were noted on the map.
- If a manhole structure was not found after field investigation or could not be opened, it was noted as "Cannot Locate (CNL)" or "Cannot Open (CNO)" in the MIAS database and forwarded to the City's Wastewater Maintenance Division for locating and opening. Once the manhole was made accessible, the inspection team was notified to revisit the site and complete the inspection.
- Once a manhole was located and opened, the MIAS survey was completed. The format of the MIAS inspection form prompted the inspector to begin their inspection by recording features such as the structure's location, and then features and defects were recorded starting at the top of the manhole structure and working down to the invert. These entries included frame/cover type and condition, and materials of construction for the chimney, corbel, barrel, bench and channel, their current condition, and evidence of I/I.
- Photographs were obtained and entered into the system for location views and top down views of the manhole; photographs were also collected for the pipe connections and any significant defects, when possible.
- Pipe sizes were recorded and located according to clock position with the outgoing pipe always in the 12 o'clock position. Pipe diameter and rim-to-invert depths were also collected and recorded in MIAS, along with the condition of the pipe seals.
- All inspected manholes were then assigned a 1-5 condition rating, with 1 being in excellent condition and 5 being in very poor condition and requiring immediate attention.

The rating was largely based on the American Society of Civil Engineer Manual of Practice 92. A summary of the inspected manhole condition ratings is provided in Table 4.2.1.

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

Table 4.2.1 - Manhole Condition Summary

Overall Rating	Description	Number of Manholes (ea)	Percent Total (%)
1	Excellent Condition	703	16.27
2	Good Condition	1959	45.35
3	Fair Condition	1481	34.28
4	Poor Condition	160	3.70
5	Immediate Action Required	17	0.39
Total Manholes Inspected:		4320	---

As indicated in Table 4.2.1, approximately 96-percent, or 4,143 manholes, of the inspected manholes were in fair to excellent condition. The remaining inspected manholes were in poor condition or required immediate action. As summarized in Table 4.2.2, nearly a quarter (24-percent) of the total observed defects was located near or in the incoming and/or outgoing sewers of a manhole. Approximately 18-percent of the total observed structural defects are located in the channel and manhole walls, and approximately 40-percent of the total defects are located in the manhole chimney, frame and/or cover.

Table 4.2.2 - Manhole Defect Summary

Manhole Component	Number of Defect (ea)	Percent of Total (%)
Cover Defect	63	0.75
Frame Defect	118	1.40
Chimney Defect	3,153	37.42
Corbel Defect	259	3.07
Barrel Defect	378	4.49
Bench Defect	911	10.81
Channel Defect	693	8.22
Pipe Defect	1,100	13.05
Pipe Seal Defect	927	11.00
Steps	824	9.78
Total Defects	8,426	---

Approximately 66-percent of the inspected manholes indicated the presence of base infiltration. As summarized in Table 4.2.3, approximately 98-percent of the total observed manhole base infiltration was generally located on the manhole walls (e.g. manhole corbel, chimney and barrel) and, based on review of the manhole inspections, all infiltration observations indicated wet or damp manhole surfaces. Moderate base infiltration was noted in the manholes located along stream valleys. The majority of the observed infiltration at manholes occurred in areas of the sewershed where the assets were built earlier than 1920.

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

Table 4.2.3 - Manhole Infiltration Location Summary

Description	Number of Defect (ea)	Percent of Total (%)
Total Manholes Inspected	4,320	---
Manholes that Leak	2,852	66.02
Frame Leaks	45	1.27
Chimney Leaks	2,678	75.59
Corbel Leaks	294	8.30
Barrel Leaks	441	12.45
Bench Leaks	52	1.47
Channel Leaks	33	0.93

A copy of the inspection database and reports is provided in Attachment 4.2.1.

4.3 Sewer Cleaning and Closed Circuit Television Inspection

Closed circuit television inspections were completed to identify sewer defects, determine the defect severity and confirm sewer connectivity. The inspections began in December 2007 and were substantially completed in November 2009. As required by Paragraph 9, Item D.ii of the Consent Decree, all CCTV inspections were completed and data collected in accordance with the National Association of Sewer Service Companies' (NASSCO's) Pipeline Assessment & Certification Program (PACP). All CCTV operators, equipment and QA/QC reviewers were certified in the use of the PACP coding system. All CCTV inspection observations were recorded using Flexidata, version 6.4 developed by PipeLogix.

Whenever possible, light cleaning using a hydraulically propelled high-velocity jet or other mechanically powered equipment was completed prior to CCTV inspection. Significant restrictions, such as roots or other heavy debris required heavy cleaning using a root cutter or additional passes of the hydro-cleaning equipment for critical sewers.

Whenever possible, CCTV inspections began at the upstream manhole and proceeded downstream to minimize splashing on the camera lens. When defects and/or obstructions precluded further advance of the camera, a reverse inspection, starting from the downstream manhole, was initiated. During the inspection, the camera was temporarily stopped at all observed defects and service connections to accurately code the observation and provide a clear image. For large diameter sewer inspections where temporary flow bypass could not effectively reduce the water level, a combination CCTV/sonar inspection was conducted (reference Section 4.7).

4.3.1 Structural/Operational Defects and Ratings

The PACP coding system requires the assignment of a specific code for each structural and O&M type defect identified within a pipe segment. The software automatically assigns a PACP rating code to each defect when entered. These grades are assigned based on the potential for further deterioration or possible failure of the pipe.

SEWER SYSTEM EVALUATION STUDY GWYNNS FALLS SEWERSHED STUDY AND PLAN

The PACP grading system obtained from NASSCO's "Pipeline Assessment and Certification Program" reference manual utilized for this project grades the defects as follows:

Grade	Description	Time to Failure
5	Immediate Attention Required	Pipe has failed or will within 5 years
4	Poor	Pipe will probably fail within 5 to 10 years
3	Fair	Pipe may fail in 10 to 20 years
2	Good	Pipe unlikely to fail for at least 20 years
1	Excellent	Failure unlikely in the foreseeable future

The structural pipe rating and other pipe characteristics (reference Section 7) are used to assign a condition and criticality rating to the sewer. Corrective action recommendations are prioritized based on the condition and criticality rating.

In general, the wastewater collection system serving the Gwynns Falls Sewershed is in fair condition. As indicated in Table 4.3.1, cracks in the sewer pipe wall, which are considered minor structural defects, were the most common structural defect observed in the CCTV inspections. The most common operational defect was root intrusion.

As summarized in Table 4.3.2, approximately 99 percent of the inspected sewers have a structural grade of 3 or less. Table 4.3.3 indicates that approximately 54-percent of the inspected sewers have an O&M grade of 3 or less, indicating that approximately half of the collection system requires some type of maintenance activity. A copy of the Flexidata database used to record all CCTV inspection information is provided in Attachment 4.3.1.

Table 4.3.1 - CCTV Defects Observation Summary

Inspection Defects		Pipe Diameter (inches)					Total (ea)	Percent of Total (%)
Family	Group Type	8-12 (ea)	14-18 (ea)	20-33 (ea)	36-54 (ea)	> 60 (ea)		
Structural	Crack	19,282	379	22	11	2	19,696	24.76
Structural	Fracture	8,036	280	1	1	3	8,321	10.46
Structural	Defective Joint	12,137	116	2	0	0	12,255	15.41
Structural	Encrustation/Scaling	2,114	137	8	3	4	2,266	2.85
Structural	Broken Pipe	3,619	64	1	0	0	3,684	4.63
Structural	Deformation	118	19	0	0	0	137	0.17
Structural	Collapse	35	2	0	0	0	37	0.05
O&M	Roots	16,962	258	68	58	11	17,357	21.82
O&M	Infiltration	794	38	13	7	1	853	1.07
O&M	Grease	3,630	90	2	0	0	3,722	4.68
O&M	Settled Deposits	1,433	61	23	54	126	1,697	2.13
O&M	Obstruction	893	29	17	7	2	948	1.19
Construction	Defective Tap	5,658	36	0	0	0	5,694	7.16
Construction	Line Deviations	325	0	12	7	39	383	0.48
Miscellaneous	Water Level >20%	297	78	8	68	56	507	0.64
Miscellaneous	Survey Abandoned	1,704	95	25	7	4	1,835	2.31
Miscellaneous	Camera Underwater	110	31	0	8	8	157	0.20

SEWER SYSTEM EVALUATION STUDY GWYNNS FALLS SEWERSHED STUDY AND PLAN

Table 4.3.2 - Sewer Structural Pipe Rating Summary

Rating	Description	Sewer Segments (ea)	Percent of Total (%)
5	Defects That Require Immediate Action	8	0.14
4	Poor - Severe Defects that will Become grade 5 in the Near Future	15	0.26
3	Fair - Moderate Defects that will Continue to Deteriorate	77	1.33
2	Good - Minor Defects that have not Started to Deteriorate	425	7.32
1	Excellent - No Defects or Minor Defects Present	5,279	90.95
Total:		5,804	---

Table 4.3.3 - Sewer O&M Pipe Rating Summary

Rating	Description	Sewer Segments (ea)	Percent of Total (%)
5	Defects That Require Immediate Action	36	0.62
4	Poor - Severe Defects that will Become grade 5 in the Near Future	65	1.12
3	Fair - Moderate Defects that will Continue to Deteriorate	202	3.48
2	Good - Minor Defects that have not Started to Deteriorate	638	10.99
1	Excellent - No Defects or Minor Defects Present	4,863	83.79
Total:		5,804	---

4.4 Smoke Testing

Smoke testing was performed to identify possible I/I sources. During the summers of 2008 and 2009, approximately 524,301 lf of sanitary sewer was smoke tested to identify possible inflow or RDII sources, such as illegal stormwater connections into the sanitary sewer collection system. A total of 26 flow meter basins were smoke tested in the Gwynns Falls sewershed. These basins were identified by the Inflow and Infiltration Analysis, completed as part of the project and included as Attachment 3.8.1. Figure 4.4.1 indicates the location of the selected flow meter basins.

Smoke testing was performed when the groundwater table was low and after sufficient time had elapsed from any prior rain events. Smoke testing was not performed until a minimum of 24-hours had passed from a significant wet-weather event so that the soils were sufficiently dry to allow smoke detection. Prior to initiating smoke testing, an extensive list of property owners, hospitals, schools, local civic and community leaders, community associations, council members, and police and fire officials were notified. This process included advanced monthly notifications and the distribution of detailed smoke testing door hanger notifications extending two city blocks outside the test areas at least three days prior to conducting the tests. When smoke testing was initiated and temporarily halted due to rain or other operational issues, the notification process was completed again. In most cases, smoke testing was conducted using a single smoke blower setup technique. Theatrical smoke was introduced at the blower location and pushed through sections of the pipe. The maximum sewer length tested was set at 1,000 lf and smoke was introduced for a minimum of five (5) minutes before any observations were recorded. Field crews were responsible for determining that adequate smoke coverage was obtained by observing smoke concentrations and smoke travel using house plumbing vents along the tested sections as visual indicators. Smoke was continually introduced into the tested sanitary sewer system until adequate smoke coverage was obtained in the test area. Due to financial and practical constraints, smoke testing was not performed on sanitary sewers 15 inches in diameter and larger, nor was

SEWER SYSTEM EVALUATION STUDY GWYNNNS FALLS SEWERSHED STUDY AND PLAN

it performed on sewers located on property owned by the Baltimore City Department of Recreation and Parks.

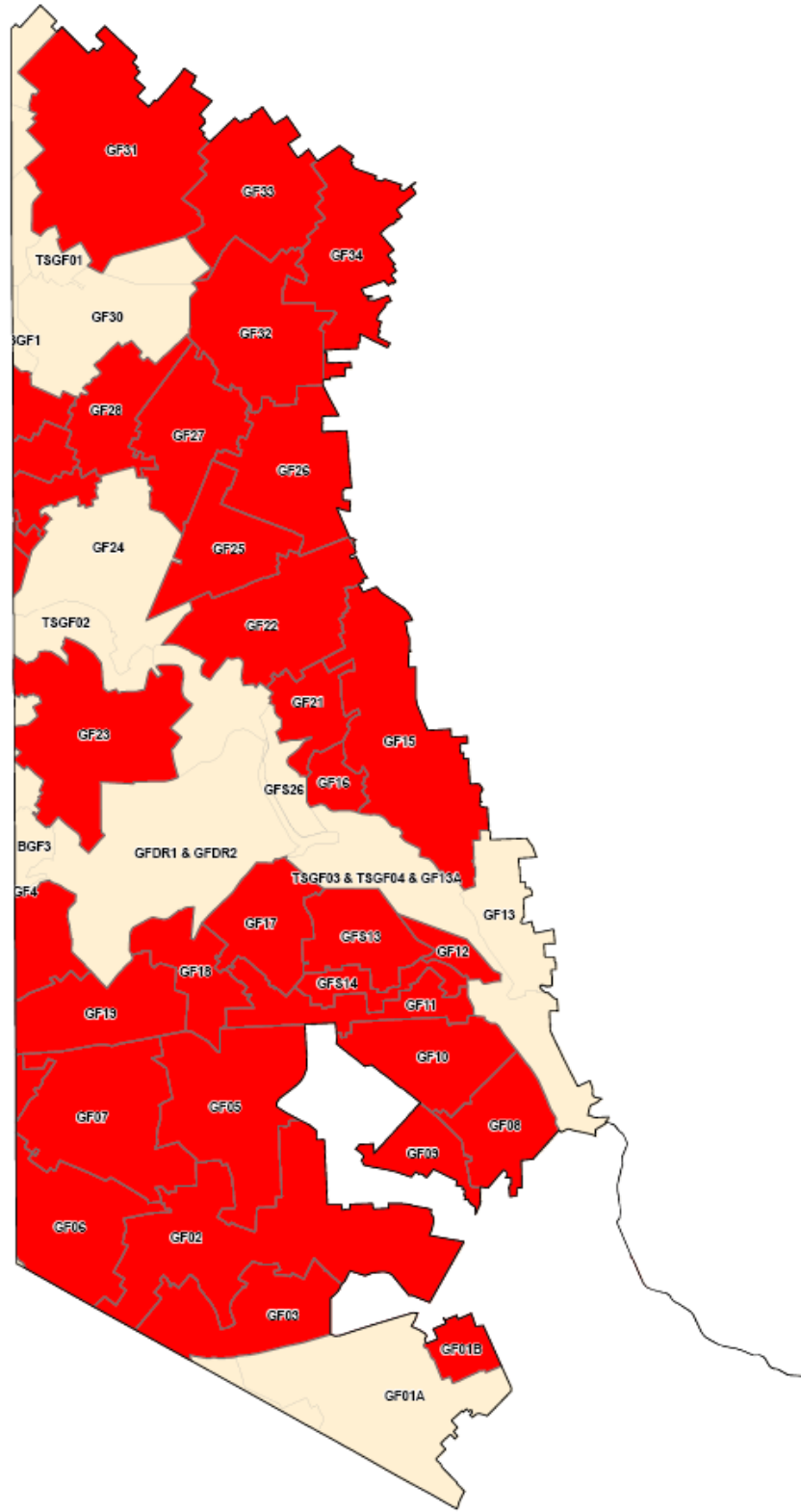


Figure 4.4.1 – Smoke Test Locations

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

Suspect inflow or RDII sources such as driveway drains, stairwell drains, window well drains, patio and area drains, downspouts piped underground, and foundation drains were noted. Significant potential sources of “clear water” connections (such as storm drain or catch basin connections) were noted and were recommended for follow-up dyed-water testing to determine if actual cross connections existed. Care was taken to inspect the property around all buildings for sources of smoke.

A summary of the smoke test defect observations is provided in Table 4.4.1.

Table 4.4.1 - Smoke Testing Defect Summary

Sector	Total Defects	Percent of Total (%)
Public	451	38.32
Private	726	61.68
Total:	1,177	---
Source Type	Total Observations	Percent of Total (%)
Service Lateral/Cleanout	595	50.55
Window Well Drain	2	0.17
Downspout	108	9.18
Catch Basin	230	19.54
Sewer Manhole	13	1.10
Main Sewer	99	8.41
Transition Joint	1	0.08
Stairwell Drain	43	3.65
Driveway Drain	2	0.17
Area Drain	6	0.51
Foundation Drain	5	0.42
Storm Manhole	31	2.63
Inside of Building	1	0.08
Others	41	3.48
Total:	1,177	---

A copy of the smoke test inspection database and reports is provided in Attachment 4.4.1.

4.5 Dyed-Water Testing

Dyed-water flooding tests were performed to confirm I/I sources. The location of each dye test was determined based on positive smoke test results. The following stormwater collection features were identified for supplemental dyed-water testing:

- i. Stormwater inlets with positive smoke test observations that were located in the public right-of-way. Based on information obtained from the respective smoke test report and associated digital photographs, the dissipating smoke density was quantified to prioritize dye floods at the locations where the existence of an illegal or illicit connection was considered most probable.
- ii. Other stormwater collection features (e.g. downspouts, yard inlets, etc.) at large commercial/residential buildings such as office buildings and apartment complexes.

SEWER SYSTEM EVALUATION STUDY GWYNNS FALLS SEWERSHED STUDY AND PLAN

Dyed-water flood tests were performed at stormwater inlets located in the public right of way where direct connections to the wastewater collection system were suspected to exist. As shown in Figure 4.5.1, dye flood tests were performed by plugging the suspected storm drain and partially filling it with dyed water. A CCTV camera inspected the sanitary sewer, observing and locating defects that permit stormwater and/or sources of infiltration into the sanitary sewer. A dyed-water flood test was determined to be positive if the existence of a direct connection was established or if dyed water was observed in the sewer main as a result of trench migration from the storm main and infiltration through joints or defects.

A minimum of six inches of standing water (as measured from Location A in Figure 4.5.1) was required to complete each test. This hydraulic condition was maintained for a minimum of 15 minutes. If dyed water was not detected in the sewer after 15 minutes, the test was abandoned and the negative test result was noted in the dye flood database.

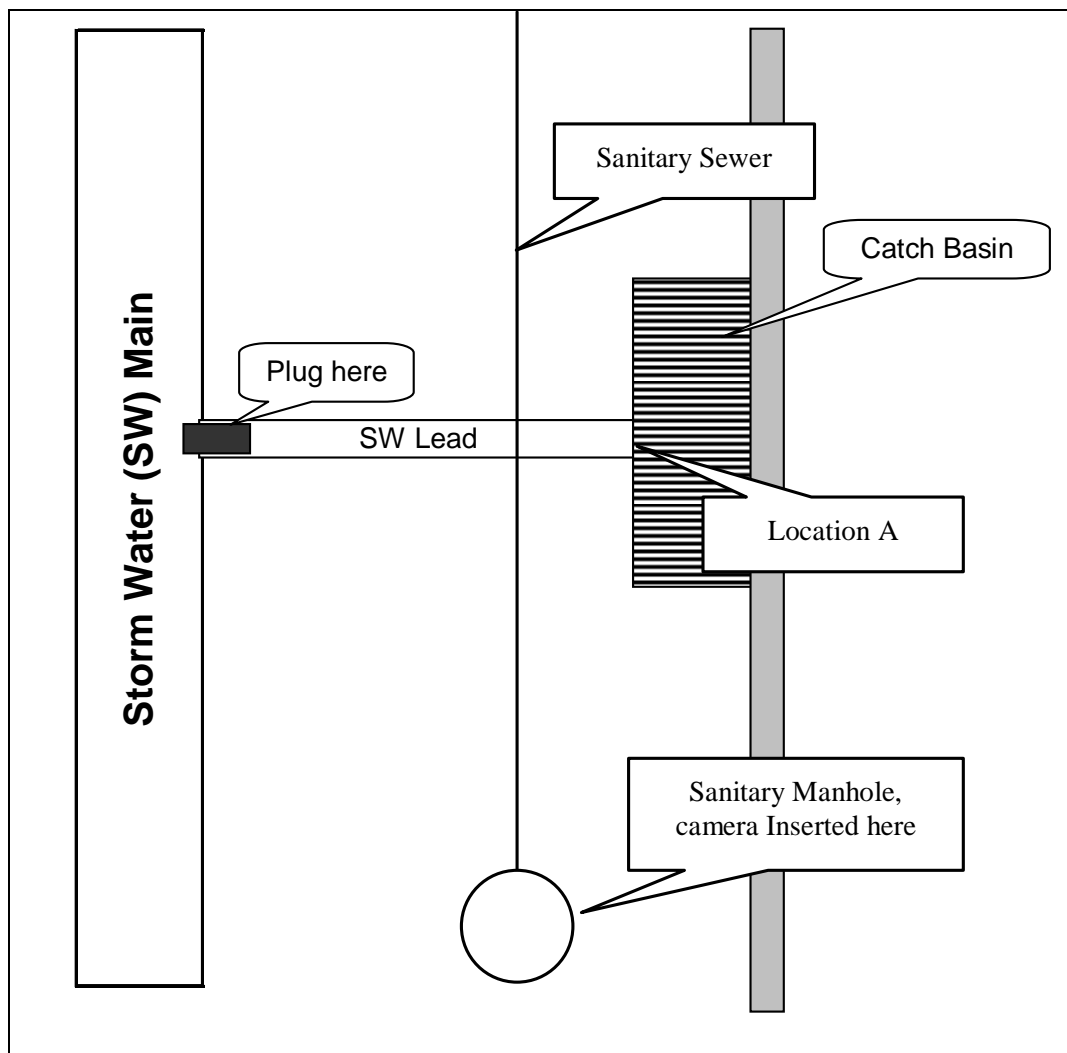


Figure 4.5.1 – Dye Flood Configuration

Dye tests were also performed at roof drains, or downspout connections, in private property for connections that tested positive through smoke test inspections. These dye

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

tests were performed in order to determine whether each downspout connection was illegal or improper, as illustrated by Figure 4.5.2. Dye roof tests were performed by inserting green dye at the cleanout location and red dye at the roof drain, or downspout, location. A CCTV camera inspected the sanitary sewer, observing and locating the point of entry of both dye colors into the sanitary sewer system.

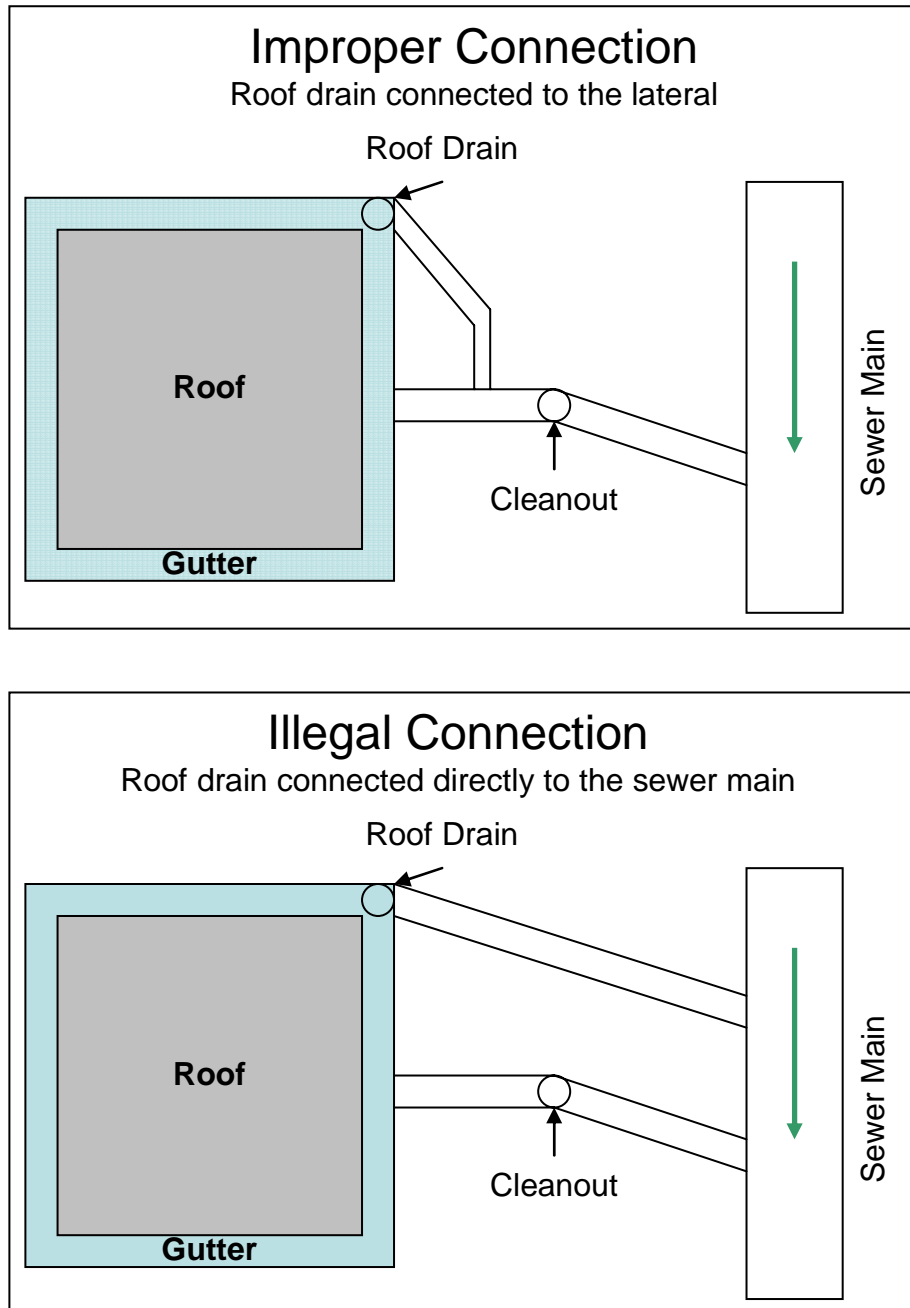


Figure 4.5.2 – Downspout Test Configuration

As shown in Table 4.5.1, a significant number of positive smoke test results at roof downspouts and various storm drain inlets are located on private property.

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

Table 4.5.1 - Dye-Water Testing Defect Summary

Sector	Total Defects	Percent of Total
		(%)
Public	79	39.30
Private	122	60.70
Total:	201	---
Source Type	Total Observations	Percent of Total
		(%)
Downspout	79	39.30
Catch Basin	122	60.70
Cleanout	0	0.00
Area Drain	0	0.00
Total:	201	---

Dye tests confirmed that there were no locations where the stormwater system was directly connected to the wastewater collection system. In general, none of the 122 dye flood tests performed at catch basins confirmed a direct connection to the wastewater collection system. However, 66 of the tests confirmed stormwater exfiltration from the storm drain entering the sanitary sewer as infiltration through various sewer defects such as cracked/broken house laterals and sewer main fractures/holes, and under manhole frame and covers. As a result of the downspout tests, 3 illegal and 76 improper connections were identified.

A copy of the dye flood inspection database and reports is provided in Attachment 4.5.1.

4.6 Emergency Repairs/Rehabilitation

In accordance with Paragraph 9 Item C.iii of the Consent Decree, all significant system deficiencies observed during field inspections or when reviewing the field data were reported to the City through the established Consent Decree communication protocols. In some cases the City's non-emergency assistance hotline (311) was also contacted. Figure 4.6.1 indicates the location of reported observed significant deficiencies.

SEWER SYSTEM EVALUATION STUDY
GWYNNNS FALLS SEWERSHED STUDY AND PLAN

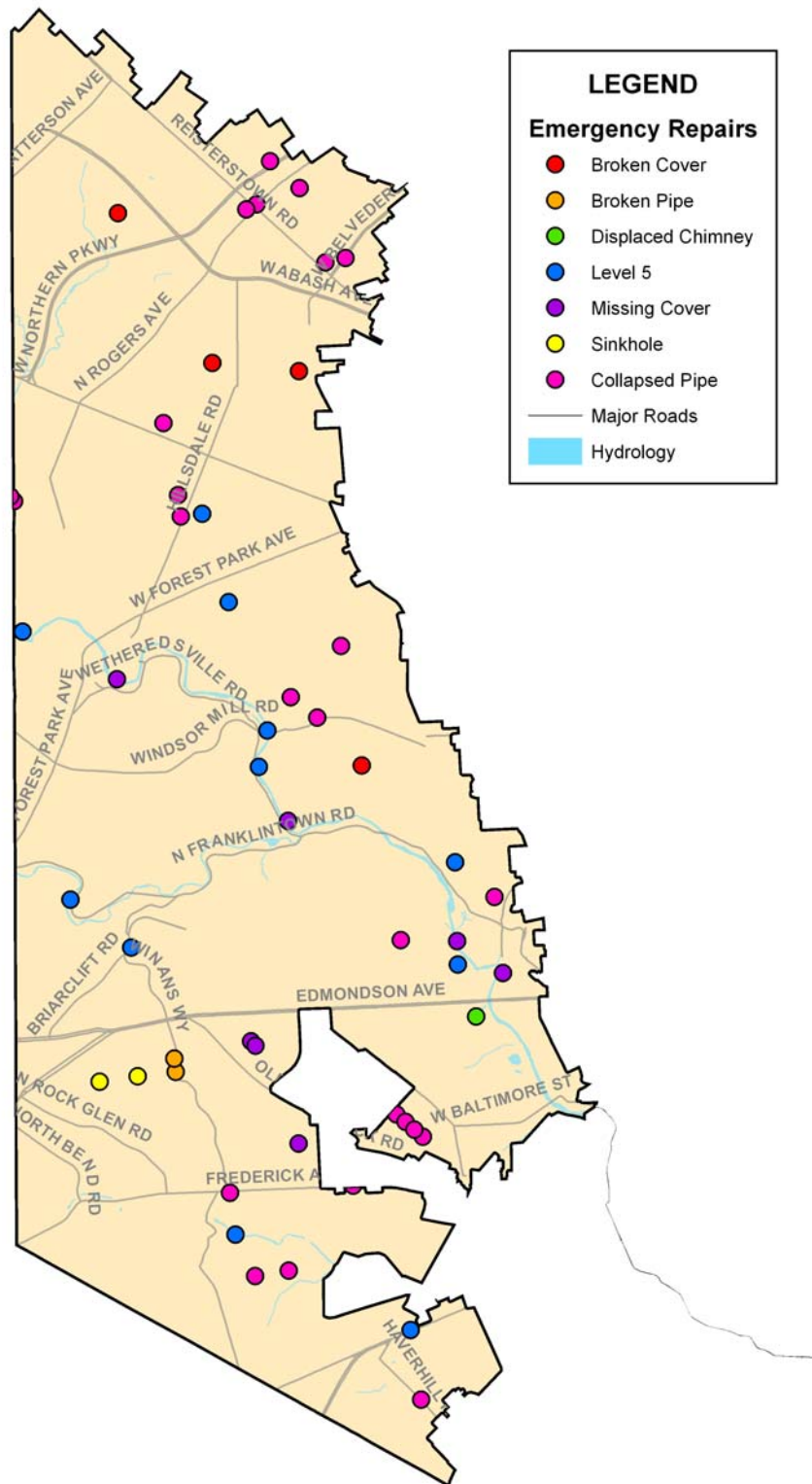


Figure 4.6.1 – Emergency Repair/Rehabilitation Locations

SEWER SYSTEM EVALUATION STUDY GWYNNNS FALLS SEWERSHED STUDY AND PLAN

4.7 South West Diversion Isolated Inspections

The South West Diversion (SWD) is a large diameter Prestressed Concrete Cylinder Pipe (PCCP) interceptor ranging in size from 66- to 106-inches in diameter that conveys sanitary sewer flow from the Gwynns Falls Sewershed to the Patapsco Wastewater Treatment Plant.

The SWD mostly operates under low pressure, full pipe flow conditions, with several segments where the pipe grade causes it to operate under open channel conditions. Due to the possibility of hydrogen sulfide attack, efforts were made to complete inspection of those open channel segments. A combination of CCTV, Sonar, and Laser Scans were used in the inspection of these segments due to the large diameter and high flow of the inspected segments.

4.8 Westport Pump Station Force Main Inspection

The Westport Pump Station Force Main is a 14-inch diameter ductile iron pipe (DIP) measuring approximately 200 feet in length. The force main was installed in the early 1980s, and conveys wastewater from the Westport Pump Station to the South West Diversion (SWD), which in turn conveys wastewater to the Patapsco Wastewater Treatment Plant. In accordance with Paragraph 9, Item D.i.a of the Consent Decree, a condition assessment of the force main was completed.

The profile of this force main indicates that there is little, if any, risk of internal corrosion. Specifically, the force main is laid with flat to increasing slope from the wet well until it discharges into the SWD. Therefore, there are no significant localized high points exist which eliminates the risk of gas entrainment that could lead to hydrogen sulfide attack. In addition, two blow-offs were installed which allow any trapped gas to escape. Finally, because this main discharges into a pressurized section of the SWD, there is no free outfall condition as the pipe is fully pressurized at all times. This information coupled with the age of the force main allows us to conclude that the risk of internal degradation is low.

Due to site characteristics, including close proximity to the Maryland Transportation Administration (MTA) light rail system and the possibility for exposure to stray currents, the force main was at potential risk for external degradation. Therefore, a test pit excavation to gather soil samples and visually evaluate the external condition of the force main was performed. In addition, soil resistivity measurements were taken in the vicinity of the force main. The results of this investigation indicate that the external condition of the pipe is relatively sound although there appeared to be minor graphitization on the underside of the pipe. The soil has resistivities which indicate that it is very corrosive and the pH appeared to be low. Based upon preliminary results it is recommended that the City install galvanic cathodic protection to the force main. A copy of the Westport Force Main Assessment Report may be found in Attachment 4.7.1.

4.9 Quality Assurance/Quality Control Protocols

All field inspection work and QA/QC reviews were completed as described in the following sections. Copies of the various field work and QA/QC protocols are provided in Attachments 4.9.1 through 4.9.4.

SEWER SYSTEM EVALUATION STUDY GWYNNNS FALLS SEWERSHED STUDY AND PLAN

4.9.1 Manhole Inspection Protocols

All manhole inspections were performed using the proprietary data management software known as Manhole Inspection Application Software (MIAS) provided by the City.

General information, such as manhole location and connectivity, was visually compared with data recorded in the City's geographic information system (GIS). Discrepancies between the two data sets were noted by the field crew on field inspection maps, which were provided with each electronic data submission. Specific condition assessment data, such as pipe depth, manhole structure material and structural and operational defects were recorded in the MIAS database by the inspector. All observed defects were photographed and cataloged in the MIAS database.

A three-level QA/QC review process was completed for each manhole inspection. A manhole inspection was not accepted until all QA/QC reviews were completed and passed. A description of each review level is provided below:

- i. Level 1 – This review was intended to provide an initial check that all required data was provided and that the data conformed with the project specifications.
- ii. Level 2 – This review provided a comprehensive check that all recorded data was accurate and that all provided information conformed with the project specifications. Connectivity information recorded in the manhole inspection was compared with the geographic information system. .
- iii. Level 3 – This review confirmed that all Level 2 review comments are correct before additional field activities were performed. Miscellaneous outstanding Level 2 review comments were addressed by the Level 3 reviewer.

Each QA/QC review level was performed by different individuals. Manholes that did not pass a QA/QC review were reassigned to a field crew for correction. The manhole re-inspections were reviewed by the same QA/QC process described above.

4.9.2 Sewer CCTV Inspection Protocols

All sewer CCTV inspections were reviewed for picture and sound quality and PACP coding conformance. Failed inspections were reassigned to a field crew for correction.

For selected sewer segments, the CCTV inspection could not be performed due to various field conditions (e.g. hydraulic conditions, camera underwater, root intrusion, debris deposition, etc.). Video inspections and other available data such as MIAS records and GIS data were reviewed to confirm abandoned inspection explanations. Unacceptable inspection abandonments were communicated to the field crews for re-inspection. The CCTV re-inspections were reviewed by the same QA/QC process described above.

4.9.3 Sonar/CCTV Inspection Protocol

All sonar/CCTV inspection footage was reviewed for picture and sound quality and data completeness. Where CCTV inspection videos were provided, all footage was reviewed as described in Section 4.9.2.

4.9.4 Smoke Testing Protocol

All smoke tests were reviewed for accuracy and completeness. Review comments were forwarded to the field crew for corrections. All data was reviewed to identify significant potential I/I sources such as storm drain inlets and roof leaders. Based on the review, dye flood tests were identified and completed.

4.9.5 Dyed-Water Testing

All dyed-water flood tests were reviewed for accuracy and completeness. In some instances, a second test was performed to confirm a direct stormwater connection to the wastewater collection system or infiltration by trench migration from the storm system.